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Research paper

Evaluation of Intake Cofferdam Work Implementation Methods At the Muara Tawar PLTGU Project

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ABSTRACT

Purpose: The construction of a new intake in the Muara Tawar PLTGU must be carried out by demolishing the existing walls of the canal. There was a shift in the intake cofferdam in the Muara Tawar PLTGU project which caused a delay in the duration of the work so that the contractor suffered losses. The evaluation of the implementation method of the intake cofferdam work aims to analyze the existing stability conditions in several conditions against shear and overturning, analyze the safety of the existing profile, redesign the cofferdam so that it does not experience a shift, and propose a new method of installing the cofferdam.

Methods/Design: The evaluation method was carried out by collecting data based on field observations and interviews with four existing conditions: (1) Cofferdam flooding due to seepage; (2) Flooding due to tides; (3) Conditions if the cofferdam is fully installed; (4) Flooding due to rain. Data analysis techniques accordance with SNI 03-1729-2000 Specifications for Structural Steel Buildings.

Findings: The evaluation results show that the intake cofferdam at the Muara Tawar PLTGU has shifted due to the absence of locks on other buildings. The shift value is obtained from the calculation of shear stability ≤ 1.5. In terms of overturning moment stability, the cofferdam experienced overturning because the overturning moment stability value ≤ 1.5. The cofferdam structure bar force fulfills in resisting the forces that occur in the cofferdam.

Practical implication: With the shift, a redesign is carried out, namely adding anchor locks to 12 joints using mechanical anchors with each baseplate using 2 22 mm diameter anchors.

INTRODUCTION (1 – 2 pages)

Muara Tawar Combine Cycle Power Plan 2, 3, & 4 Add On 650 Project is the name of the project to add 3 electricity production blocks. The project is worth IDR 2,109 billion with the contractor PT. Hutama Karya and Doosan Heavy. The PLTGU production system requires two main fuel sources to carry out production. The fuel for electricity production at PLTGU is gas and water. PLTGU Muara Tawar collaborates with the state gas company to fulfil gas as the main ingredient for electricity production. Meanwhile, water is obtained from the sea and will be processed. The entry of sea water will be through the Circulating Water Intake (CW Intake) building. The CW Intake add-on project was built by demolishing the existing retaining wall. CW Intake blocks 2, 3 and 4 will be built next to CW Intake block 1 and block 5 which are already actively producing electricity. All additional buildings for blocks 2, 3 and 4 were made similar to blocks 1 and 5 with the same layout. Construction starting from the Balance of Plant (BOP) and Power Block is still in one area and adjacent to other blocks. CW Intake is built on an existing canal with a concrete-based canal floor. For this reason, appropriate work methods are needed for the construction of add on CW Intake blocks 2, 3 and 4.

Figure 1. Cofferdam Shift

As time increases, the use of the cofferdam method as protection against the destruction of existing retaining walls is experiencing problems. This obstacle is in the form of a shift in the position of the cofferdam due to tides. Shifting of the cofferdam causes leaks in the work area, disrupting the work of dismantling the existing wall. With the disruption of existing demolition work, the work had to be postponed and resulted in the contractor experiencing losses

The purpose of discussing these problems includes:

1. Determine the stability of shear forces and the stability of overturning moments that occur in the intake cofferdam of the Add on Block 2, 3 and 4 PLTGU Muara Tawar Project.
2. Know the security profile IWF 200.200.8.12 on the existing cofferdam.

3. Know an effective design so that the cofferdam does not shift.
4. Propose a new cofferdam installation method.

METHODS

The method used is to analyse the cofferdam in four conditions, namely the existing condition experiencing seepage, the existing condition experiencing flooding due to sea tides, the existing condition if it is installed perfectly, and the existing condition when flooding occurs due to rain. The initial stage of the study begins with a literature review which contains information on calculation standards and other information that can support the calculation analysis. The literature review was obtained from literature, lecture teaching materials, Indonesian National Standards (SNI 03-1729-2000), and journals regarding steel roof structures. After the calculation standards are determined, data in the form of image documents and other documents can be analysed. Analysis calculations use manual calculations and are assisted by FEM software. Several steps taken:

1. Collection of data related to cofferdam planning for the Muara Tawar PLTGU Project.
2. Determine the materials used in cofferdam construction and the loads that occur.
3. Structural calculation analysis was carried out by reviewing the structural components and cofferdam supports
4. Plan cofferdam redesign considering safety and equal loading.

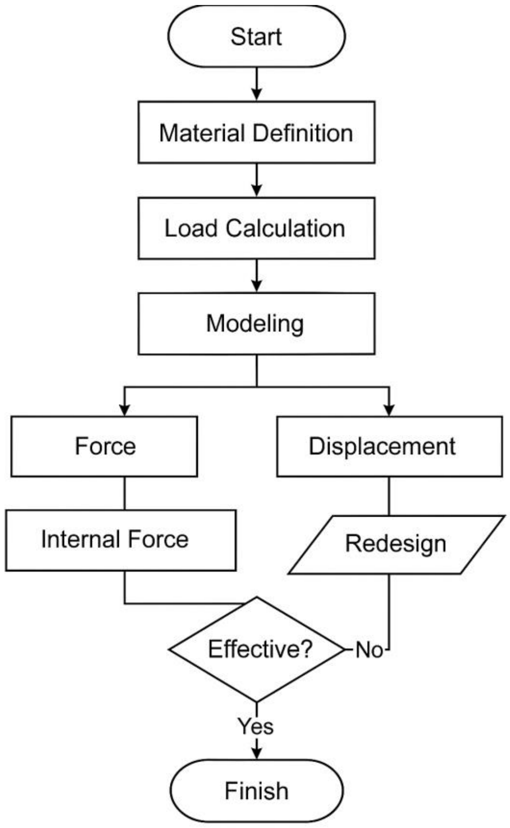

Figure 2. Flow Chart Data Analysis

Data analysis on the cofferdam structure is carried out in the following way:

1. Analyse the loads acting on the cofferdam structure and look for structural reactions due to the loads.
2. Calculating the sliding and overturning safety factors on existing cofferdams.
3. Plan appropriate and safe connections to lock the cofferdam to prevent shifting.
4. Plan methods that can be used for cofferdam installation work.

FINDINGS

1. Research Data

The material used for the cofferdam in the Muara Tawar PLTGU project is steel. The steel material used refers to JIS G3101 SS400 or ASTM A36. In JIS (Japanese Industrial Standard) SS400 is structural steel which has a grade of 400, while in ASTM (American Standard Testing and Material) the same steel is classified as grade 36. The weight of the cofferdam structure is 127.47 kN.

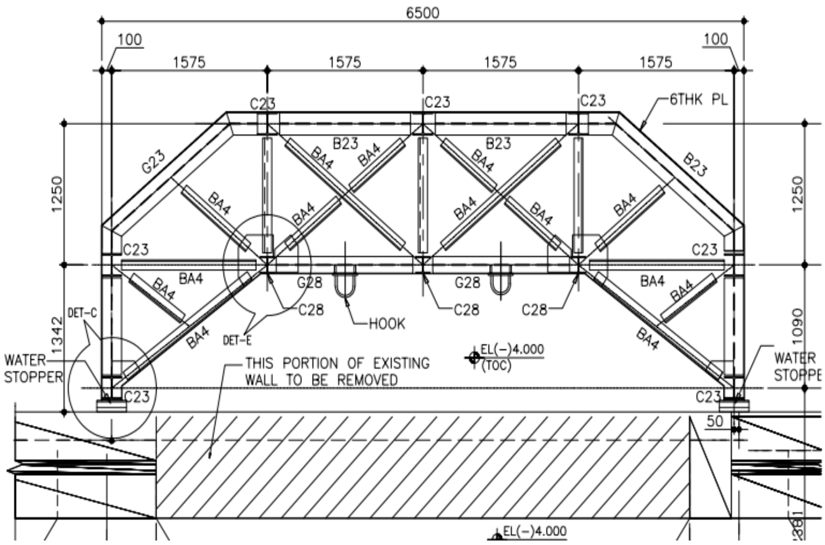

Figure 3. existing cofferdam design

Analysing drawings of the cofferdam structure on the Muara Tawar PLTGU project. The images reviewed include images of the existing canal walls, buildings around the cofferdam, and details of the cofferdam design.

Table 1. Data on the steel material used

Profile Steel Parts		Mark	Unit
Steel yield stress	(f_{yk})	245	MPa
Body height	(d_t)	200	mm
Wingspan	(b_f)	200	mm
Body thickness	(t_w)	8	mm
Wing thickness	(t_f)	12	mm

The cofferdam used is made from various types of steel profiles and steel plates as cofferdam walls. The steel profile refers to PT's steel product catalogue. Mount Garuda. The following types of steel are used in cofferdam structures.

Table 2. Dimension of Steel Profile

Type	Dimension		Weight
	H X B	A	
	mm	cm2	kg/m
IWF	200 x 200	63.53	49.9
IWF	150 x 150	40.14	31.5
Equal Angel	90 x 90	17	8.28

Furthermore, the water level has been measured based on four conditions and described based on the canal water level and the cofferdam water level on the table 3.

Table 3. The Water levels

Type	Dimensi		Weight
	H X B	A	
	mm	cm2	kg/m
IWF	200 x 200	63.53	49.9
IWF	150 x 150	40.14	31.5
Equal Angel	90 x 90	17	8.28

Apart from the cofferdam data, water level data in the canal was obtained PLTGU Muara Tawar in several conditions. Water level height at Channels can change according to natural conditions. This data is based on field observations and interviews conducted with workers in particular intake section. Several water level elevation conditions in the canal.

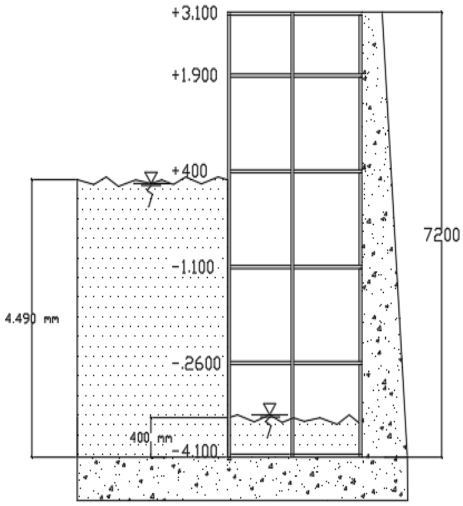

Figure 4. Water Level Height Condition 1

2. Shear and Roll Analysis

Analysis of existing conditions is carried out by calculating force or pressure which can affect the cofferdam structure. Because the cofferdam is in the canal or in direct contact with water, hydrostatic pressure will increase affect the cofferdam, in addition to the cofferdam hydrostatic pressure will also get the gravitational force. After all the compressive forces are calculated then It can be seen that the compressive force acting in the vertical direction is obtained from the weight cofferdam and horizontal compressive forces result from hydrostatic effects water in the cofferdam. These two pressing forces will be used for checking the stability of the cofferdam against shifting.

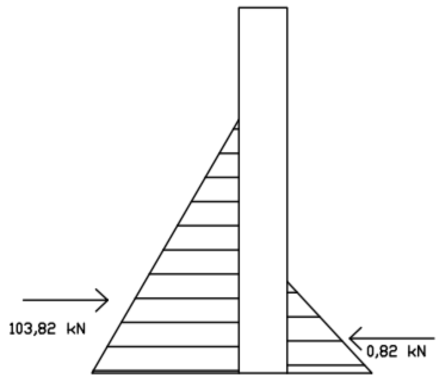

Figure 5. Direction of force in condition 1

The load that occurs on the cofferdam consists of the load due to the hydrostatic pressure of the water and the load on the cofferdam itself. Where the hydrostatics of water can be obtained from the following equation.

$$Pa = \frac{1}{2} \gamma h2 \quad (1)$$

To determine the stability of sliding, you can use the equation.

$$Sf = f \frac{\Sigma V}{\Sigma H} \quad (2)$$

Rolling stability is also calculated by:

$$F_{gl} = \frac{M_w}{M_g} \quad (3)$$

The safety value for sliding and rolling stability is declared safe if it exceeds 1.5. Cofferdam hydrostatic pressure occurs so that the loading produces the following forces.

Table 4. Load

Condition	Active Load (Pa)	Passive Load (Pp)
1	103.82 kN	0.82 kN
2	185.4 kN	0.20 kN
3	103.82 kN	0 kN
4	144.66 kN	31.16 kN

By knowing all these forces, shear stability and rolling stability can be produced as in table 5

Table 5. Sliding and Rolling Stability

Condition	S_f	Description	F_{gl}	Description
1	0,37	*Unacceptable*	0,42	*Unacceptable*
2	0,2	*Unacceptable*	0,24	*Unacceptable*
3	0,36	*Unacceptable*	0,42	*Unacceptable*
4	0,33	*Unacceptable*	0,38	*Unacceptable*

3. Profile Strength Analysis

When planning a steel structure, you must pay attention to the strength of the steel rods used to carry the load that occurs. Calculation of the strength of steel bars can be done in the following way:

a. Calculation of nominal moments due to local buckling effects
   Compact cross section, l ≤ lp
   Mn = Mp
   Non-compact cross section, lp < l ≤ lr
   Mn = Mp - (Mp - Mr) . (l - lp) / (lr - lp)
   Slim cross section, l > lr
   Mn = Mr . (lr / l)2 (4)
b. Nominal moment of lateral buckling influence
   Short span: L ≤ Lp
   Mn = Mp = fy . Zx
   Medium span: Lp ≤ L ≤ Lr
   Mn = Cb . [Mr + (Mp - Mr) . (Lr - L) / (Lr - Lp)](8)
   Long span: L > Lr
   Mn = Cb.p/ L.√[E.Iy.G.J + (p . E / L)2 .Iy.Iw] (5)
c. Bending Moment Resistance
   Mux / (fb . Mnx) + Muy / (fb . Mny) ≤ 1.0 (6)
d. Shear Resistance
   Vux / (ff . Vnx) + Vuy / (ff . Vny) ≤ 1.0 (7)
e. Shear and Flexure Interaction
   Mu / (fb . Mn) + 0.625 . Vu / (ff . Vn) ≤ 1.375 (8)

After analyzing with FEM software, the largest bar force output is produced as follows.

(M_{ux}) =	133591847,7	Nmm
(M_{uy}) =	131759963,1	Nmm
(V_{ux}) =	167627	N
(V_{uy}) =	162085	N

The rod style in the IWF 200.200.8.12 profile used for the cofferdam can be concluded that the profile has a compact flange, including a short span and adequate shear resistance. The above review concluded that the profile is safe. Apart from that, the results of the shear and bending interaction control calculations meet the requirements. With this, the cross-section of the cofferdam profile does not need to be redesigned. The following are the results of the IWF 200.200.8.12 rod force analysis on the existing cofferdam profile.

Table 6. IWF Profile strength 200.200.8.12

No	Reaction	Result	Information
1	Bending moment	0.43	OK
2	Shear resistance	0.92	OK
3	Shear and bending interactions	0.82	OK

4. Anchor Planning

Anchor connection planning refers to (SNI 03-1729-2000) Specifications for Structural Steel Buildings. Planning the connection can be done using the LRFD method.

a. Concrete bearing resistance

$$q \quad = \frac{Pu}{Y} \tag{9}$$

b. Support plate thickness

$$q \quad = \frac{Pu}{Y}$$

c. Bolt pulling force

$$T_u = (q_{max} . Y) - P_u \tag{10}$$

d. Bolt shear force

$$V_{u1} = \frac{V_U}{n} \tag{11}$$

e. Combination of drag and slide

$$F_{nt} = 0{,}75 \ + \ fu^b \tag{12}$$

$$F_{nv} = 0{,}45 \ + \ fu^b \tag{13}$$

f. Anchor support resistance

$$R_n = 2{,}4 \, . \, d \, . \, t \, . \, fu^p \tag{14}$$

The cofferdam shift occurred because there was no locking of the cofferdam with other buildings around it. Due to this, design improvements are needed to prevent the cofferdam from shifting. Effective cofferdam design planning by locking using anchors on the cofferdam profile and existing walls. The cofferdam shift value is high because the modeling uses a two-point joint approach by looking at shifts in the X and Y directions, so anchor planning will be carried out on 12 joints with existing conditions experiencing flooding due to sea tides. After modelling in FEM software, the force, displacement and moment values are obtained that Pu = 20.545,05 N, Mu = 17.956.284 Nmm and Vu = 25,492,99 N

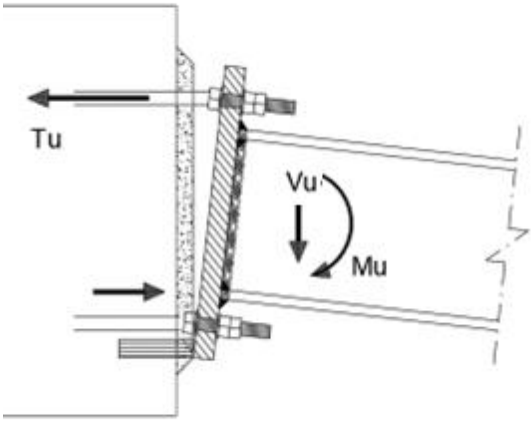

Figure 6. Illustration of Bolt Support

The anchor used is a mechanical anchor type. The use of mechanical anchors is to shorten installation time so that it is more efficient and has anchor strength that can bond with concrete walls. The anchor used is a strong bolt wedge anchor type measuring 19 mm in diameter and 200 mm long in accordance with the specifications in the Simpson Strong-Tie anchor factory catalogue. The following is the planning data for the anchor bolts used on the Table 7. The results of anchor planning using anchors with a diameter of 19 mm produce the Table 8.

Table 7. Planning data for the bolt anchors used

Category	Result
Steel yield stress	454 MPa
Plate breaking tensile stress	862 MPa
Anchor diameter	19 mm
Number of threads per inch	10 mm
Anchor length	200 mm
Plate/washer ring thickness	30 mm
Number of pressure side bolt anchors	1 pc
Number of pull side bolt anchors	1 pc
Number of rows of x direction bolt anchors	1
Number of rows of x direction bolt anchors	1

Table 8. The results of anchor planning using anchors

No	Force	Occurring Force	Maximum Design Strength	Note
1	Concrete support pressure	2850 N/mm	8425.63 N/mm	OK
2	Tensile force	40.189 N	138.629 N	OK
3	Shear force	12.746 N	73.304 N	OK
4	Combination of shear and tension	325.72 MPa	484.76 MPa	OK
5	Bolt anchor style	12.746.5 N	379.620	OK

From the results above, it can be concluded that the locking plan using anchors with a diameter of 19 mm is safe. Locking with anchors according to the plan on the baseplate and anchor requirements can be seen in the Table 9.

Table 9. Locking with anchors according to plan

No	Baseplate Point	Number of anchors	Anchor Diameter
1	10	2	19
2	18	2	19
3	135	2	19
4	143	2	19
5	117	2	19
6	126	2	19
7	99	2	19
8	107	2	19
9	83	2	19
10	91	2	19
11	58	2	19
12	66	2	19

5. Implementation Method

a. Make a mud pool

Making mud pools is done by excavating the soil around the cofferdam work. Excavation using a PC 78 excavator is easy to do. The dimensions of the pond and the depth of the excavation depend on the area where the cofferdam will be placed. This excavation aims to accommodate mud and sand deposits at the bottom of the canal in the cofferdam area.

b. Assemble Tripod Crane

The tripod crane is installed on the concrete floor of the CWPH (Circulation Water Pump House) building. Narrow access means that the tripod crane segment must be transported using a tower crane. Transport to the location according to the segments to be assembled. The assembly is done manually with the help of hand tools. After the tripod crane circuit is installed, connect the electricity to the generator.

c. Cofferdam Area Cleaning

The base of the canal floor must be cleaned of material. Material cleaning within a 15-meter radius around the cofferdam area. The aim of cleaning is at a distance of 15 meters so that waste material carried by water currents does not end up in the cofferdam area. The main object in cleaning activities is waste material with large dimensions. For example, leftover building materials that are under water, wood waste, plastic waste with large dimensions and coral that is attached to existing walls. Coral residue from plants and aquatic animals attached to existing walls must be cleaned thoroughly.

d. Dredging

Mud and sand at the bottom of the canal will affect the performance of the cofferdam. Therefore, dredging activities are needed. Dredging activities aim to remove mud and sand from the bottom of the canal in the cofferdam placement area by moving the mud and sand at the bottom of the canal to a storage or sediment pond. Dreging is done by sucking up mud and sand using a high capacity pump on a simple boat and then channeling it using an HDPE pipe to a holding pond.

e. Lifting Cofferdam

After the tripod crane and cofferdam have been rubberized on the part that will stick to the concrete, lift the cofferdam using a tripod crane. The cofferdam placement process is placed according to the planned point. Lower the cofferdam and try to make contact with the existing wall. The lowering process is carried out slowly and carefully. The rigger and operator must work together so that the cofferdam matches the point that the surveyor has made.

f. Close the canal floodgates

The closure of the canal sluice gates is carried out at the same time as the lifting of the cofferdam so that the closing time of the canal sluice gates and the work can be completed in less than 3 hours. Closing the sluice gate if done for more than 3 hours will of course affect the electricity production of other blocks that are already active. Therefore, workers installing scaffolding and workers tasked with installing anchors must be ready.

g. Put up scaffolding

Scaffolding is made of iron pipes strung above the water surface. Scaffolding is installed by lowering the scaffolding using a tower crane. Installation of scaffolding according to both sides of the cofferdam where anchorage will be carried out. The size of the scaffolding is also adjusted to the position of the anchor installation.

h. Installation of anchors

Installation of steel anchors must be done in the right way and in a short time. The anchor installation was carried out by four groups, namely the inner anchor installation group (2 groups) and the outer cofferdam installation group (2 groups). Installation is carried out at two points together, starting from the bottom anchor then moving to the top point.

Based on the application results of the temporary cofferdam in the Shenzhen–Zhongshan river channel, it is found that the overall stability and overturning stability of the cofferdam meet the relevant safety requirements, with minimum safety factors of 1.744 and 1.400, respectively. The maximum displacement of the inner and outer steel piles is 34 mm, the maximum bending moment is 249.30 kN m, and the maximum shear force is 266.66 kN. The pile displacement is within the acceptable range, and the internal force remains below the load capacity of the pile type selected for design. (Jiang et all, 2023)

The boundary balance design theory is used to calculate the load limits on the cofferdam, considering the core fill of the dam and the sheet piles on both sides as a medium and a continuous elastic shell, while also analyzing the deformation based on various boundary conditions. (Buhan et al, 1996) A simplified two-dimensional (2D) model has been developed to analyze the structure of the steel sheet pile cofferdam and to investigate the characteristics of force deformation during construction according to the calculation program they developed (Lefas et al, 2001) The failure of a double-row steel sheet pile cofferdam has been analyzed using finite element software and low tie weld strength was identified as the cause of damage to the structure (Gui et al, 2009)

Steel piles have a rich history and have undergone significant development in Europe and Japan since their introduction in the early 20th century. These piles have been widely used in various construction applications, including dams, foundation supports at docks, bridges, underground tube tunnels, and other projects. Steel piles offer many advantages such as high quality, simple construction, durability, and the ability to reduce space requirements for construction tasks (Yang et al, 2020; Wu et al, 2023)

CONCLUSION

The results of the review of analytical calculations and discussion regarding the evaluation of the PLTGU Muara Tawar cofferdam, it can be concluded that: Existing cofferdam from seepage conditions, flood conditions due to sea tides, conditions if the cofferdam is installed perfectly, and flood conditions due to rain change with cofferdam shear stability value ≤ 1.5. Judging from the rolling stability, the cofferdam experienced overturning because the rolling stability value of the cofferdam in four conditions was ≤ 1.5. The results of the IWF 200.200.8.12 steel profile bar force calculation used are short spans with adequate shear resistance. In addition, the control of the shear and bending interactions that occur meets the requirements. Thus, the existing steel cofferdam cross-section does not need to be redesigned. Redesign of the cofferdam was carried out to resist shifting by using anchor locking connections on the existing canal walls so that the cofferdam does not shift. There are 12 baseplate points with each baseplate using 2 anchors with a diameter of 19 mm. The proposed method for carrying out cofferdam work includes creating mud pools, assembling tripod cranes, cleaning, dredging, lifting, closing canal sluice gates, installing scaffolding and installing anchors.

DISCLOSURE STATEMENT

contains statements that guarantee and ensure that there is no potential conflict of interest from the author.

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